VOLUME XXXVII NUMBER 1 WHOLE NUMBER 320

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR, C. A. CHANT ASSISTANT EDITOR, F. S. HOGG
David Dunlap Observatory
Richmond Hill P.O., Ont.

ASSOCIATE EDITORS

R. MELDRUM STEWART
Dominion Astronomer
Ottawa

J. A. PEARCE
Head Astronomer
Dominion Astrophysical Observatory
Victoria, B.C.

J. PATTERSON
Controller of the Meteorological Service of Canada, Toronto

PUBLISHED MONTHLY
(Ten numbers per year)

January, 1943

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. XXXVII, No. 1 JANUARY, 1943 WHOLE No. 320

Articles PAGE

Isaac Newton: Born Three Hundred Years Ago (with Plate I) ..... *C. A. Chant* 1

Newton and Chemistry ..... *Douglas McKie* 17

The Origin of the Lunar Features ..... *R. A. McIntosh* 24

Notes and Queries

Newton Tercentenary Celebrations——*R.J.N.*; Nova Puppis 1942—*C.A.C.*; Newton's Reflecting Telescope—*C.A.C.* 29

Meetings of the Society

At Winnipeg—Victoria—Toronto 33

Upon request, made previous to publication of article, contributors will be supplied free with twenty-five copies of the sheets containing the article attached to a printed cover.

Extra copies about as follows:

	4 pp.	8 pp.	12 pp.	16 pp.	20 pp.	24 pp.
50 copies....	$3 50	$5 50	$9 50	$10 00	$13 00	$16 00
100 copies....	4 00	7 00	10 00	11 00	14 00	18 00
200 copies....	4 50	8 00	11 00	12 00	15 50	20 00

Covers, extra, 50 copies, $1.50; 100 copies, $2.00; 200 copies, $2.50.

Address of Editors: David Dunlap Observatory, Richmond Hill, Ont.

Business correspondence, remittances, etc., should be addressed to J. H. Horning, Treasurer of the Society, 198 College Street, Toronto.

$2.00 per annum. Single numbers, 25 cents.

Subscription to the JOURNAL is included in membership fee.

Visitors to Toronto who wish to get in touch with the Society are invited to telephone:

General Secretary—Mr. E. J. A. Kennedy, WA. 6363.
Assistant Secretary—Miss E. M. Budd, RA. 7186.
Chairman of Toronto Centre—Rev. Dr. D. W. Best, LL. 0555.

For Sale—10-inch Reflector; 3 eyepieces; no stand. May be seen any morning or evening by appointment only. H. A. Waddington, 31 Gould St., Toronto.

For Sale—3-inch Refractor by Ottway, London, F32 on page 18 of their Catalogue of Telescopes. For particulars inquire of Tel. HU. 2503, Toronto.

PRINTED IN CANADA

Inadvertently omitted from the end of the article by Francis P. Morgan in the December 1942 issue, p. 444.

Here the twisting effect of rotation causes the stars and dust to intermingle more freely, but there is still a tendency for separation into local star clouds and dark nebulae, each of which revolves around the centre as an independent unit. This condition is present in our galaxy in the neighbourhood of the sun.

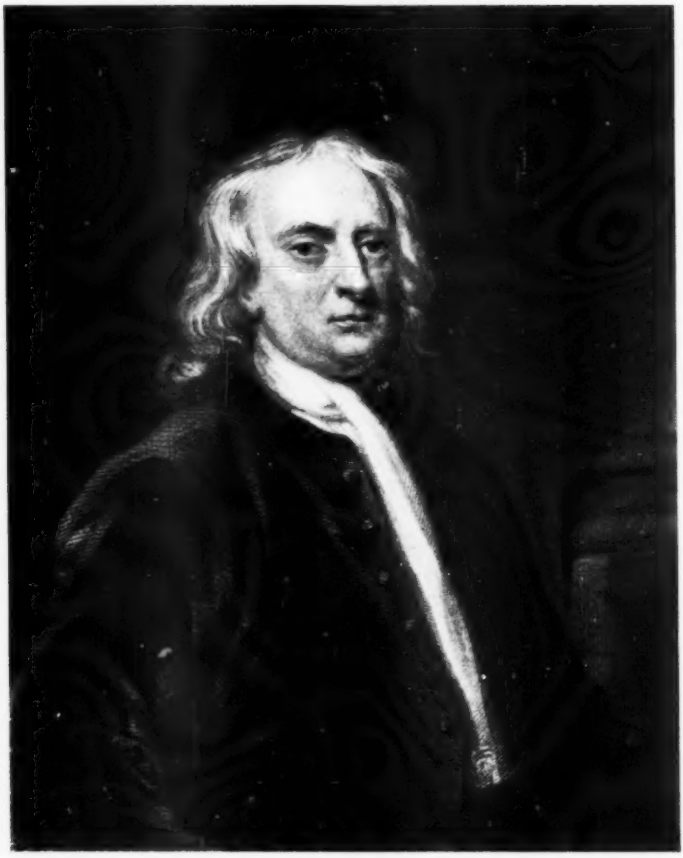
In the nuclear region the condition is much the same as in elliptic nebulae, as described above.

To summarize, the nebula sequence from elliptic to open spirals becomes mainly a measure of rotational velocity. The increase of resolution along the sequence is a measure of the brightness and frequency of the brightest stars, which for some reason is associated with rotational velocity.

There are still other problems to solve, as for example, the differences between normal and barred spirals, and the many peculiar types, but there is little doubt that in these, as in the normal types, the effects of radiation pressure play an important role.

9th October 1942
Montreal, Quebec

PLATE I



ISAAC NEWTON, 1642-1727

From the Original Picture by Vanderbank in the possession of the Royal Society.

THE JOURNAL

OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

VOL. XXXVII, No. 1 JANUARY, 1943 WHOLE No. 320

ISAAC NEWTON: BORN THREE HUNDRED YEARS AGO*

By C. A. CHANT

(With Plate I)

His Boyhood and School Days

ISAAC NEWTON was born on Christmas Day, 1642, in the small manor house of the hamlet of Woolsthorpe, about six miles south of the town of Grantham in Lincolnshire, England. His father, whose name also was Isaac, had died in the previous October; and the infant, born prematurely, was very small and very weak. However, he quickly gained strength, and his mother, who is described as kind and understanding, two years later married a mid-aged clergyman named Barnabas Smith and went to live in a near-by parish. He had sufficient income to make her comfortable. The child was left at Woolsthorpe in the care of his grandmother. In 1656 the mother became a widow again and with three more children returned to Woolsthorpe.

The little Isaac first attended two small day schools near enough for him to live at home. Then in 1654 he went to the King's School at Grantham, a long-established and good school, and there he remained for four years. The headmaster, named Stokes, found the boy gentle and teachable, but without indications of any marked ability. He was fond of reading and especially skilful at making mechanical models and toys.

Then at his mother's request he returned home to help her manage the farm. That part of the country suffered much from the civil

*Read before the Toronto Centre of the R.A.S.C., December 8, 1942.

wars of Cromwell's time and no doubt, as she now had a considerable family, she expected the lad of sixteen would be useful in helping her to provide for them all. But she was entirely mistaken. Instead of looking after the sheep or cattle or attending to other farm duties, he would be found reading a book or carving a stick with his jack-knife. His mother found that he was not suited for the life of a farmer, and headmaster Stokes urged her to allow him to return to the Grantham school,—indeed he offered to remit his fees if she would do this. So back he went in the autumn of 1660 to prepare for college, and after a single school-year he entered Cambridge University June 5, 1661, in his nineteenth year.

When at Grantham, Newton lived in the household of an apothecary named Clark, Mrs. Clark and Newton's mother being friends. The Clarks treated the boy in a kindly way and exerted a good influence on him. They encouraged him in constructing various objects, in performing chemical experiments and in drawing birds, beasts, ships and mathematical schemes. With the latter he covered the walls of his room. For this sort of work he had a real talent. Clark had a step-daughter, Miss Storey, and she and Isaac became very friendly. Indeed it is said that they were engaged to be married, but she had no "portion" and his prospects were not promising and so the engagement was broken off. But he always had kind thoughts for her and in later years visited her several times. She was married twice and in her old age was able to quote some verses which young Isaac had composed and placed under a picture of King Charles I.

Newton had a great thirst for information on all sorts of things. There are in existence two notebooks which he had at Grantham and Cambridge. One of these, the second and later one, is in the Portsmouth Collection of manuscripts and memoranda left by Newton; but the first one, after dropping out of sight of more than a century, turned up amongst the manuscripts of the Pierpont Morgan Library in New York. It is dated 1659. In it are sections devoted to "Arts Trades & Sciences," "Birds," "Beasts," "Minerals," etc.; also there are samples of perpetual calendars, astronomical tables and geometrical problems. It should be mentioned also that there are two pages of notes on the Copernican system; from them developed his investigations into the law of universal gravitation.

The second book has entries made while a student at Cambridge. We may quote some of them:

	£	*s*	*d*
Drills, gravers, a hone, a hammer and a mandril	0	5	0
A magnet	0	16	0
Compasses	0	3	6
Glass bubbles	0	4	0
My Bachelor's account	0	17	6
At the tavern several other times	1	0	0
Cloth, 2 yards and buckles for a vest	2	0	0
The Hist. of the Royal Society	0	7	0
Lost at cards twice	0	15	0
At the tavern twice	0	3	6
A Bible binding	0	3	6
For oranges for my sister	0	4	2

From the above we should conclude that the young Newton was a pretty normal boy, perhaps somewhat "companionable." He was not a prodigy but had a great fund of general intelligence.

However, Newton was not the usual type of country boy. He did not indulge freely in boyish games or scraps with his fellows. From the circumstances of his birth he probably lacked ruggedness of body, and he feared being bullied. But it is on record, in his early Grantham schooldays:

> When he was the last in the lowermost class but one, the boy next above him, as they were going to school, gave him a kick in his belly which put him to a great deal of pain. When school was over, Newton challenged him to fight, and they went into the churchyard. While they were fighting the Master's son came out, and encouraged them by clapping one on the back and winking at the other. Isaac Newton had the more spirit and resolution, and beat him till he would fight no more.... Determined to beat him also at his books, by hard work he finally succeeded, and then gradually rose to be the first in the school.

When interviewed in her old age, Miss Storey, who knew him more intimately than anyone else, states:

> Sir Isaac was always a sober, silent, thinking lad, and was never known scarce to play with the boys abroad, at their silly amusements; but would rather choose to be at home, even among the girls, and would frequently make little tables, cupboards, and other utensils for her and her playfellows, to set their babies and trinkets on.

But he had a capacity for concentration and thoroughness, he liked solitude and he did not freely reveal his thoughts to others.

wars of Cromwell's time and no doubt, as she now had a considerable family, she expected the lad of sixteen would be useful in helping her to provide for them all. But she was entirely mistaken. Instead of looking after the sheep or cattle or attending to other farm duties, he would be found reading a book or carving a stick with his jack-knife. His mother found that he was not suited for the life of a farmer, and headmaster Stokes urged her to allow him to return to the Grantham school,—indeed he offered to remit his fees if she would do this. So back he went in the autumn of 1660 to prepare for college, and after a single school-year he entered Cambridge University June 5, 1661, in his nineteenth year.

When at Grantham, Newton lived in the household of an apothecary named Clark, Mrs. Clark and Newton's mother being friends. The Clarks treated the boy in a kindly way and exerted a good influence on him. They encouraged him in constructing various objects, in performing chemical experiments and in drawing birds, beasts, ships and mathematical schemes. With the latter he covered the walls of his room. For this sort of work he had a real talent. Clark had a step-daughter, Miss Storey, and she and Isaac became very friendly. Indeed it is said that they were engaged to be married, but she had no "portion" and his prospects were not promising and so the engagement was broken off. But he always had kind thoughts for her and in later years visited her several times. She was married twice and in her old age was able to quote some verses which young Isaac had composed and placed under a picture of King Charles I.

Newton had a great thirst for information on all sorts of things. There are in existence two notebooks which he had at Grantham and Cambridge. One of these, the second and later one, is in the Portsmouth Collection of manuscripts and memoranda left by Newton; but the first one, after dropping out of sight of more than a century, turned up amongst the manuscripts of the Pierpont Morgan Library in New York. It is dated 1659. In it are sections devoted to "Arts Trades & Sciences," "Birds," "Beasts," "Minerals," etc.; also there are samples of perpetual calendars, astronomical tables and geometrical problems. It should be mentioned also that there are two pages of notes on the Copernican system; from them developed his investigations into the law of universal gravitation.

The second book has entries made while a student at Cambridge. We may quote some of them:

	£	*s*	*d*
Drills, gravers, a hone, a hammer and a mandril	0	5	0
A magnet	0	16	0
Compasses	0	3	6
Glass bubbles	0	4	0
My Bachelor's account	0	17	6
At the tavern several other times	1	0	0
Cloth, 2 yards and buckles for a vest	2	0	0
The Hist. of the Royal Society	0	7	0
Lost at cards twice	0	15	0
At the tavern twice	0	3	6
A Bible binding	0	3	6
For oranges for my sister	0	4	2

From the above we should conclude that the young Newton was a pretty normal boy, perhaps somewhat "companionable." He was not a prodigy but had a great fund of general intelligence.

However, Newton was not the usual type of country boy. He did not indulge freely in boyish games or scraps with his fellows. From the circumstances of his birth he probably lacked ruggedness of body, and he feared being bullied. But it is on record, in his early Grantham schooldays:

> When he was the last in the lowermost class but one, the boy next above him, as they were going to school, gave him a kick in his belly which put him to a great deal of pain. When school was over, Newton challenged him to fight, and they went into the churchyard. While they were fighting the Master's son came out, and encouraged them by clapping one on the back and winking at the other. Isaac Newton had the more spirit and resolution, and beat him till he would fight no more.... Determined to beat him also at his books, by hard work he finally succeeded, and then gradually rose to be the first in the school.

When interviewed in her old age, Miss Storey, who knew him more intimately than anyone else, states:

> Sir Isaac was always a sober, silent, thinking lad, and was never known scarce to play with the boys abroad, at their silly amusements; but would rather choose to be at home, even among the girls, and would frequently make little tables, cupboards, and other utensils for her and her playfellows, to set their babies and trinkets on.

But he had a capacity for concentration and thoroughness, he liked solitude and he did not freely reveal his thoughts to others.

A Student at Cambridge

The University had suffered greatly during the long civil war. Its resources had been wasted, the number of students had been reduced and the discipline had been relaxed. In general the University had been subservient to royalty, it had submitted to the appointment of heads and scholars by royal mandate and indeed had thus incurred the hostility of parliament. The new knowledge of the Continent resulting from the scientific ideas of Galileo and Descartes had not yet leavened Oxford and Cambridge. Francis Bacon, a loyal son of Trinity College, and the great apostle of inductive philosophy, could not shake the smothering influence of Aristotle's metaphysics. Astrology and superstition were still very prevalent. Philosophical and theological controversies, leading to no useful conclusions, were the common occupation of the scholars.

It is probable that Newton when he entered Cambridge had been trained chiefly in the Latin and Greek classics, perhaps with some ancient and biblical history added. As to mathematics, only elementary arithmetic would likely be required.

Newton before he left home had received from his uncle Ayscough a copy of Sanderson's *Logic* which, he was told, was the first book he would be required to read. He studied it so thoroughly that when he took lectures on the subject he was quite as familiar with it as was his tutor, Benjamin Pulleyn, Regius Professor of Greek, who was greatly impressed and became his friend.

Professor More in his biography of Newton gives the following outline of Newton's studies in science:

> From Newton's own notes we know that he spent the first two years at college learning arithemtic, Euclid, and trigonometry. He also read, or listened to, lectures on the Copernican system of astronomy. For most of his work after the Easter Term in 1663 he was under the direction of Barrow, the newly appointed Lucasian Professor, who also taught him natural philosophy and, most significant of all, optics. This science, which for the first time offered to him a serious opportunity to use his experimental skill, evidently fascinated him and first brought out his latent powers of invention. In addition to following the course of lectures on light, he read Kepler's *Optics*, probably during the vacation, and that study was undoubtedly the cause of his interest in telescopes and the properties of light. His mastery of the subject was so thorough that, when Barrow shortly afterwards published his lectures, he turned to his youthful pupil for criticism and revision of the manuscript.

Newton obtained his knowledge of the system of analytical geometry invented by Descartes from the standard texts on the subject written by Oughtred, van Schooten, Vieta, Wallis and the inventor himself. To this subject he gave much attention in the summer of 1664. Amongst his notes there are calculations relating to musical scales; observations on the refraction of light, the grinding of lenses and their errors, which led to important results later; and also problems on the extraction of mathematical roots, which led to his discovery of the Binomial Theorem.

Professor More continues:

> The extraordinary thing to bear in mind, in this catalogue of his undergraduate studies, is not so much that Newton thoroughly mastered these subjects as that he so digested them and meditated upon their inherent possibilities that they awoke his creative powers. In a few short years, each subject led directly and unerringly to a masterpiece of genius, and, a still more astonishing fact, these years provided the germ of all his discoveries.

In January 1665 Newton received the B.A. degree along with twenty-five other students of Trinity College. There is no record of his standing in the class. He had learned to use the tools of mathematics, and a few months later he committed to writing some new ideas which had come to him. These later became his method of Fluxions which is the same as the differential calculus.

At this time the great plague was spreading over England, and on August 8, 1665, the College was dismissed. Newton went back to Woolsthorpe where he remained in seclusion almost two years. The results of his stay there are unparalleled in the history of science. He was but 23 years old and before this had not shown any great intellectual precocity, and yet by intense meditation and pondering over the ideas which had come to him he arrived at three of the outstanding achievements of the human mind. These were (1) the mathematical method of fluxions, (2) the law of the composition of light, and (3) the law of universal gravitation. In a memorandum which he drew up about 1714 Newton might well remark, "All this was in the two plague years 1665 and 1666, for in those days I was in the prime of my age for invention, and minded mathematics and philosophy more than at any time since."

Lucasian Professor of Mathematics

On July 7, 1668, Newton was given the M.A. degree, and on October 29, 1669, he was appointed Lucasian Professor of mathematics, the professorship being named for its founder, Henry Lucas. It is one of the illustrious chairs of science and its occupants have included many eminent mathematical physicists. The appointment was directly due to Isaac Barrow who recognized Newton's outstanding ability and retired in his favour. Newton had sent Barrow a paper entitled "On analysis by equations with an infinite number of terms," which Barrow described as a work of unparalleled genius and he resigned his chair and returned to his theological studies.

The duties of the position were not very onerous. Newton was required to lecture once a week during one term of the year, and to give two conferences a week to students while he was in residence. Often, however, no students turned up for the lectures and the conferences were seldom held. Newton now had sufficient time to pursue his meditations and researches and an ample income, probably £200 per annum.

For the subject of his first course of lectures Newton chose Optics and he continued it through two years. The lectures as they were read were deposited amongst the archives of the University and many copies of them were taken; and as some of them were garbled and imperfect the original notes were ultimately prepared for publication, but the work did not appear until 1729, two years after the author's death. It must not be confused with Newton's well known treatise entitled *Opticks*, the first edition of which came out in 1704 and the fourth in 1730, while a reprint was issued in 1931.

In 1664 Newton made some observations on light with a prism, and early in 1666 he figured and polished lenses, using in these operations machines which he himself had constructed. His experiments with these lenses suggested the unequal refrangibility of the different rays of light, which he studied in great detail. As a consequence he constructed a reflecting telescope. News of this instrument leaked out and he was urged to send it to the Royal Society. In the meantime the telescope was lost and Newton had to make another, which was sent to the Royal Society where it created much interest. But it also disappeared and Newton made a third telescope and pre-

sented it to the Royal Society in 1671. It attracted much attention and was examined by many, including King Charles II. It is now one of the cherished possessions of the Society. This incident led the Bishop of Salisbury to propose Newton for membership in the Royal Society and he was elected January 11, 1672.

This pleased Newton greatly and he promised to send the Society an account of his recent work on light. The paper was sent to the Society on February 6. In it Newton describes with precision the various experiments he had made with two glass prisms through which sunlight was passed, and then he states his conclusions, which I quote at considerable length:

1. As the rays of light differ in degrees of refrangibility, so they also differ in their disposition to exhibit this or that particular colour. Colours are not qualifications of light, derived from refractions, or reflections of natural bodies (as it is generally believed) but original and connate properties, which in divers rays are diverse. Some rays are disposed to exhibit a red colour, and no other; some a yellow, and no other; some a green, and no other; and so of the rest. Nor are there only rays proper and particular to the more eminent colours, but even to all their intermediate gradations.

2. To the same degree of refrangibility ever belongs the same colour, and to the same colour ever belongs the same degree of refrangibility. The least refrangible rays are all disposed to exhibit a red colour, are all the least refrangible; so that the most refrangible rays are all disposed to exhibit a deep violet colour, and contrarily, those which are apt to exhibit such a violet colour, are all the more refrangible. And so to all the intermediate colours, in a continued series belong intermediate degrees of refrangibility. And this analogy betwixt colours, and refrangibility is very precise and strict; the rays always either exactly agreeing in both, or proportionally disagreeing in both.

3. The species of colour, and degree of refrangibility proper to any particular sort of rays, is not mutable by refraction, nor by reflection from natural bodies, nor by any other cause, that I could yet observe. When any one sort of rays has been well parted from those of other kinds, it has afterwards obstinately retained its colour, notwithstanding my utmost endeavours to change it. I have refracted it with prisms, and reflected it with bodies, which in daylight were of other colours: I have intercepted it with the coloured film of air interceding two compressed plates of glass; transmitted it through coloured mediums, and through mediums irradiated with other sorts of rays, and diversely terminated it; and yet could never produce any new colour out of it. It would, by contracting or dilating, become more brisk, or faint, and by the loss of many rays, in some cases very obscure and dark; but I could never see it change in specie. . . ."

How modern it all reads! A physicist of to-day could hardly

suggest any improvement in the method of experimenting or in the presentation of the results. But the scientists of the time could not appreciate the work. They did not have the proper scientific attitude in carrying out an investigation, but still clung to speculations drawn from their inner consciousness. There was much discussion of Newton's paper, both in England and on the Continent, and at last Newton became greatly annoyed and said he would not publish anything further; "for," said he, "I see a man must either resolve to put out nothing new, or to become a slave to defend it." Newton sent no more contributions on light to the Royal Society, but he continued his experiments and his meditations on their meaning. When, many years later, his *Opticks* was published he concluded it with a series of Queries relating chiefly to the nature of light. He was acquainted with the wave-theory and the hypothetical ether of space, and he thought deeply on the corpuscular theory. It is commonly supposed that he definitely decided in favour of the latter; but he did not whole-heartedly adopt any theory of light. In this he showed scientific ability or perhaps we may call it intuition. At the beginning of the nineteenth century the striking experiments of Young and Fresnel led to an almost universal acceptance of the wave-theory; but now, alas! following discoveries in radio-activity, the discharge of electricity through gases, and the theoretical discussions of Lorentz and Einstein, all is uncertain again—light is to us simply light!

The Theory of Universal Gravitation

As I have said, one of Newton's great "inventions" when at Woolsthorpe during the plague, was his theory of gravitation. Of course this subject had been pondered upon for centuries, but with no useful results. A body fell to the earth, it moved along a radius toward the earth's centre, and this action was described by saying that the earth *attracted* it. According to the evidence of Newton's niece, there is reason to believe that Newton was led to ponder this matter by the fall of an apple as he sat in the orchard. Objects from the height of the house fell to the earth, also from a tall tree; what about the distance of the moon? Now the force exerted by the earth on a piece of matter is measured by the distance it falls in one second when dropped from rest. From Kepler's Third Law Newton had deduced

that the force of attraction of the earth on the moon should be inversely as the square of the distance of the moon from the earth's centre. This distance he knew to be 60 times the radius of the earth. He then computed how far the moon is drawn toward the earth each second, "and," he says, "thereby compared the force requisite to keep the moon in her orb with the force of gravity at the surface of the earth, and found them answer pretty nearly." This was in 1666.

No further progress was made in this matter for many years and there is a tradition, based on good authority, that Newton's calculation was not quite satisfactory to him although he declared it to "answer pretty nearly." The reason, it is stated, was that taking a degree of latitude to be 60 miles he had deduced a wrong value for the earth's radius; and he did not repeat the calculation until 1682 when he learned of Picard's accurate value. But a close scrutiny of the facts shows that several much more accurate values of a degree were well known in 1666 and, further, that Picard's value was published in 1671 and immediately recognized in England. Also it is known that there were in Newton's library two books which had better values of a degree than the one he used. It would almost appear that Newton decided from his preliminary calculation that the moon was held in its path by gravity, and being busily engaged with other investigations he allowed the gravitation problem to stand.

Many able men had suspected that the planets moved in their elliptical orbits under the influence of an attractive force from the sun varying inversely as the square of the distance; and at a friendly meeting in January 1684 Edmund Halley, Christopher Wren and Robert Hooke seriously discussed the question. Halley and Wren stated that they were unable to solve the problem but Hooke asserted that he had demonstrated all the celestial motions on that principle. Wren challenged him to produce his demonstration and offered him a prize. He did not do so, however, and in August Halley went up to Cambridge to consult Newton about it. Halley asked him what would be the curve described by the planets on the supposition that gravity diminished as the square of the distance. Without hesitation Newton answered, an ellipse, and said he had proved it some years earlier. Being asked for the calculation, he could not find it but he promised to send it to Halley. He had lost his notes and had to

solve it afresh. This he did by two different methods and sent the solution to Halley.

In this way Newton's interest in the subject was re-awakened and by October he had worked out enough problems to serve as material for nine lectures which he delivered during the Michaelmas term under the title, *De Motu Corporum*. Halley was delighted to receive Newton's demonstration and journeyed back to Cambridge to tender his thanks. While there Newton showed him his new *De Motu Corporum* material and, realizing its importance, he urged Newton to publish it. He consented, and in revising the manuscript it grew into a much larger work entitled *Philosophiae Naturalis Principia Mathematica*, which those who can appreciate it have declared to be the greatest intellectual feat in the history of science.

Fluxions or the Differential Calculus

The third Herculean achievement at Woolsthorpe during the plague was the "invention" of Fluxions. This was a new mathematical method, fundamental in all modern mathematics and simply indispensable in the solution of physical problems in which force and motion are involved. An independent discoverer of the method was Leibnitz in Germany, a little later. Indeed other mathematicians, for instance, Wallis in England and Fermat in France, were almost on the threshold of its discovery, and it has been said that it was "in the air." Newton was quite willing to accept the statement that Leibnitz was an independent discoverer, but when it was stated on the Continent that Newton was guilty of plagiarism he simply boiled over, and there arose a fierce controversy which lasted for many years and indeed was never satisfactorily settled. If Newton had published his discoveries soon after he made them questions of priority would not have been raised. But he was secretive and self-centred. He was calm and remote, and indifferent to the contemporary reception of his work. He had no desire for fame but was passionately concerned with the fact that his discoveries were original with himself and not plagiarized from anyone else. In his first paper, that on Light, referred to at length above, he adopted a pleasant and friendly manner, but the *Principia* was composed "in a style of glacial remoteness." In a letter giving permission for a mathematical result of his to be published, providing his name be not divulged, he states his reason thus: "For

I see not what there is desirable in public esteem, were I able to acquire and maintain it. It would perhaps increase my acquaintance, the thing which I chiefly study to decline."

This is a suitable place to refer to two incidents in Newton's life long after he had given up active mathematical research. In June 1696 John Bernoulli, a famous Swiss mathematician and a strong partisan of Leibnitz, challenged "the acutest mathematicians of the world" to solve two problems which he proposed and which illustrated well the peculiar power of the differential calculus. He allowed six months for the solutions, but at the request of Leibnitz, who had solved one of them, the time was extended a year longer. On January 28, 1697, the challenge was received by Newton from France, and on the very next day he sent solutions to the President of the Royal Society. Then in 1716, twenty years later, Leibnitz, in a postscript to a letter to the Abbé Conti, offered a problem "for the purpose of feeling the pulse of the English analysts." It was to determine a curve with certain specified properties. Newton received the problem at 5 p.m., while on his way home from a tiring day's work, and he solved it that night before going to bed. Newton was extraordinarily swift of apprehension, and when once he really concentrated on a question he moved straight to its solution. It is said that when Bernoulli read in the *Transactions* of the Royal Society for January 1697 the anonymous solutions to his problems he recognized the author from the sheer power and originality exhibited—"tanquam ex ungue leonem" (just as from its claw one knows a lion).

Newton's Chemical Experiments

Newton did not devote himself entirely to mathematics and physics. When attending school at Grantham he began his experiments in chemistry in apothecary Clark's shop, and they grew to be one of the great interests of his life. This subject was most congenial to his tastes and aptitude and he gave more time to it than to any other. But the chemistry of that day was rather alchemy, as the scientific foundation for what we now understand as chemistry had not been laid. Some of the ablest men of the time, such as Hooke, Boyle and Locke, were alchemists. Their chief aim was the transmutation of the elements, such as iron into copper or lead into gold. Also, there

were earnest efforts to discover a universal panacea for old age—the elixir of life! During many years Newton did much experimenting. Even when he was in the intellectual throes of creating the *Principia* he and his assistant kept the fires under his alchemical crucibles glowing all day and all night long. He made many notes on the results of his experiments, but nothing of permanent value was achieved.*

In Newton's library were many books on chemistry, a considerable number dealing with alchemy and magic. At first he firmly believed that the objects sought by the alchemists were attainable, but as he grew older he became more sceptical.

Newton was forty-four when the *Principia* was published. He lived another forty years but never again seriously concerned himself with scientific investigations.

Newton a Member of Parliament

Up to the completion of the *Principia* in May 1686 Newton apparently gave little thought to anything outside the walls of Trinity College. But in the late years people in the rest of England were agitated by the acts of their rulers. James II ascended the throne in 1685. He was a strong Roman Catholic and it soon became evident that he intended to destroy the Established Church. Now the universities of Oxford and Cambridge were strong buttresses of the Church and against them his early attacks were directed. On the 9th of February 1687 the Vice-Chancellor of Cambridge University received a letter signed by the king ordering the University to admit Alban Francis, a Benedictine monk, to the degree of M.A., without requiring him to take the oaths of allegiance and supremacy as demanded by law.

The University authorities at once recognized that the king was attempting to override their regulations, which were based on the civil law. Some were in favour of a compromise, but the "Congregation" voted otherwise, holding that the admission of Francis without the usual oaths was illegal and unsafe. On April 11 the Senate appointed the Vice-Chancellor and eight other Fellows, one of whom was Newton, to represent the University before the newly and illegally

*See, however, the paper on "Newton and Chemistry" by Dr. Douglas McKie, immediately following.

revived High Court of Commission, presided over by the notorious Chancellor Jeffreys, who adopted his usual method of browbeating them, but they did not yield.

Newton was not a ready speaker but he stiffened the resistance of the others and the delegation resolved to make no compromise.

The king then abandoned his attempt to coerce the universities. But it was too late. Some of the nobility opened negotiations with the Prince of Orange regarding his taking a part in settling the affairs of the nation. In June 1688 a son was born to James. This was the last straw! All hope of a Protestant succession was gone. The Peers then invited William of Orange to head the Protestant cause; and by December he had mastered the country and James had fled to France. Writs were now issued for the election of a Convention Parliament which should settle the succession to the throne and bring order to the country. The University of Cambridge, remembering Newton's firm stand against encroachments by the late king, elected him as one of its representatives, and on January 22, 1689, he took his seat in the House of Commons. He held his seat until the parliament was dissolved in February 1690. Without doubt Newton was a useful committeeman, but he had not the quickness of mind desirable in a parliamentary leader. He did not impress William III with his aptitude for public affairs. It is reported that at one time when the king was in a political difficulty he was advised to consult Newton, but his reply was, "Newton is merely a philosopher."

A new House of Commons had now to be elected and Newton was a candidate, but he was unsuccessful. However this experience in politics had changed his outlook on life. One of the most brilliant men in the House was Charles Montague, who was a friend of Newton's in Trinity College. Newton met many other leading men, and mixed in society.

In 1689 Newton's mother was stricken with a malignant fever. He went to her and skilfully nursed her himself, but the illness proved fatal. This intensified his desire for a change. But nothing definite was before him and he returned to Cambridge, February 4, 1690, to his old position.

In 1692 and 1693 Newton suffered a partial mental breakdown. This has been attributed to his labours on the *Principia,* his irregular

hours and his restlessness as he looked for a new position. But on March 19, 1696, his friend Montague wrote informing him that he had been appointed Warden of the Mint at a good salary. Surely a strange position for a mathematician and philosopher! But it was not so. The task of recoinage was just begun, and it seemed that when Newton seriously meditated on any problem he reached useful results. In three years he carried the great project to complete success. He was then made Master of the Mint, which position he held until his death. His salary was about £2000 a year.

Newton was elected M.P. again shortly after resigning his professorship in December 1701. That parliament however was dissolved on July 2, 1702, shortly after the death of William III.

In 1703 Newton was elected President of the Royal Society and he was re-elected every year until his death in 1727. In April 1705 Queen Anne bestowed a knighthood on him, a singular recognition at that time for a man like him. He was the first English man of science to be honoured thus.

Theology and Chronology: Flamsteed

Newton was a member of the Established Church and a staunch Protestant and he gave much time and thought to religious studies. These related chiefly to the doctrine of the Trinity—in which he was rather heterodox—and to the prophetic books of the Bible—especially Daniel and the Revelation of St. John. He considered these investigations of great importance—much more so than his researches in science. He published several papers, the most important being, "Two Notable Corruptions of Scripture," namely I John v. 7 and I Tim. iii. 16, which refer to the Trinity. But they all have little interest for us at the present day, while his discoveries in science render his name for ever illustrious. He was the greatest of all scientific geniuses but he did not consider science of the first importance.

To the subject of chronology also he gave close attention. He wrote a small book on *Chronology* which, without his knowledge, was first printed abroad in French. It was seriously criticized and Newton was roused to action. Although he was 81 years old and suffering from stone, gout, and inflammation of the lungs, he set

about preparing a detailed account of his system in proper form to be printed. This big task occupied almost three years, but it was not published until after his death—a volume of 376 quarto pages. However, the foundations on which he built were insecure and the results he reached are valueless.

Reference must also be made to the controversy between Newton and Flamsteed. The Greenwich Observatory was founded in 1675 and Flamsteed was the first Astronomer Royal. Now Newton was a mathematical astronomer and required observations to check his theories, while it was Flamsteed's business to make observations of the heavenly bodies. One would expect the two men to co-operate closely. But Flamsteed was suspicious and irritable and Newton certainly lacked tact. Further, Halley was a friend of Newton and of him Flamsteed most heartily disapproved. The result was a series of unpleasant altercations between Newton and Flamsteed, forming a painful chapter in the history of astronomy. As one reads the correspondence between the two men one cannot but believe that Newton was somewhat at fault. He was almost implacable and would not go half-way when Flamsteed made approaches of friendship.

Personal Characteristics: Death

During the years 1685-1690 Newton had an assistant named Humphrey Newton—not a relative—who describes his employer thus:

> His carriage was then very meek, sedate, and humble, never seemingly angry, of profound thought, his countenance mild, pleasant and comely. I cannot say I ever saw him laugh but once . . . I never knew him to take any recreation or pastime in riding out to take the air, walking, bowling, or any other exercise whatever. . . . He very rarely went to bed till two or three of the clock, sometimes not until five or six, lying about four or five hours.

Until the closing years of his life his health was good. He never wore spectacles and retained all his teeth but one. His hair was abundant but turned grey at thirty and later became silver-white. He had piercing brown eyes, as revealed by his portraits, was a man of medium height and had a vigorous constitution.

For the sake of his health Newton in 1724 moved out to the village of Kensington. Here rest and country air was of great benefit to him, but he insisted on going into London occasionally. One of these visits brought on his last illness. A little before his death he said:

I do not know what I may appear to the world; but to myself I seem to have been only like a boy, playing on the sea-shore, and diverting myself, in now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me.

On Tuesday, February 28, 1727, Newton went to London to preside at a meeting of the Royal Society. He stayed in town until Saturday, March 4, and was taken ill on arriving home. On March 15 he seemed a little better and on the 18th he was perfectly clear in his mind, read the newspaper, and conversed freely with his friends. That evening at six he became insensible and between one and two o'clock on March 20, he passed away. On April 4 he was buried in Westminster Abbey.

On a stone tablet over the fireplace in the room in which Newton was born is inscribed Pope's famous couplet:

Nature and Nature's Laws lay hid in night;
God said, Let Newton be—And all was light.

ACKNOWLEDGMENT

The 200th anniversary of the death of Newton was commemorated in March 1927. It was realized at that time that no satisfactory biography of Newton existed. Work on a new one was begun then and after years of labour in consulting original sources there appeared:—

Isaac Newton a Biography, by Louis Trenchard More, xxii+675 pp., Scribner's, 1934.

It is scholarly, precise, appreciative, full of information regarding contemporary conditions as well as Newton himself, and gives numerous references to authorities. Another recent valuable work is:

Isaac Newton 1642-1727, by J. W. N. Sullivan, xxii+275 pp., Macmillan, 1938.

This is an expansion of a brilliant and discriminating article in *The Times Literary Supplement* for March 17, 1927, which was reprinted in this JOURNAL, vol. 21, p. 144, 1927. It makes considerable use of Professor More's biography, and my paper is much indebted to both volumes.

C.A.C.

NEWTON AND CHEMISTRY*

By Douglas McKie

ISAAC NEWTON was born in the manor-house of Woolsthorpe-by-Colsterworth, a few miles south of Grantham, Lincolnshire, on Christmas Day, 1642. He was the posthumous child of Isaac Newton and his wife, Hannah Ayscough. He was educated at the King's School, Grantham, and entered Trinity College, Cambridge, in June 1661, graduating in January 1664/5.

Interrupted in his further studies through the dispersal of the students owing to an outbreak of the plague, Newton returned to his home at Woolsthorpe. There, in enforced vacations extending from the summer of 1665 to the spring of 1666/7, he invented the differential calculus and discovered the composition of light and the law of universal gravitation. Any one of these would have meant immortal fame. Yet all three fell to Newton when he was in the twenty-third and twenty-fourth years of his age. Returning to Cambridge, he was elected a Fellow of Trinity College, took his M.A. degree, and in 1669, in his twenty-seventh year, was appointed Lucasian Professor of Mathematics in succession to his teacher, Isaac Barrow, who wished to relinquish the Chair in order to study theology. In 1687 Newton published his *Philosophiae Naturalis Principia Mathematica,* that sublime achievement of the human intellect.

But Newton, like many lesser men, loathed the drudgery of mathematical work, and it was to his relief that he was appointed Warden of the Mint in March 1695/6, and then Master in 1699, when the recoinage of the silver was completed. The change from Cambridge to London seems to have been to his liking. He was elected President of the Royal Society in 1703 and re-elected at successive intervals until his death. He took an active part in the Society's meetings and conscientiously discharged the duties of his office. He

*Reprinted from *Endeavour* of October 1942, pp. 141-144. This publication is "a quarterly review designed to record the progress of the sciences in the service of mankind," and is admirably printed and illustrated. It is issued by Imperial Chemical Industries, London, England. The author of this article is Lecturer in the Department of the History of Science in the University of London.—*Editor.*

died on 20th March, 1726/7, in his eighty-fifth year, hale and vigorous almost to his last days. His body lay in state in the Jerusalem Chamber in Westminster Abbey from 28th March, and on 4th April was buried in the Abbey near the entrance to the Choir .

Newton's achievements in mechanics are generally known to scientfic readers. His chemical studies are less well known and often dismissed as "alchemical." Newton was very far from being a man of remote academic interests. He had a very practical mind; in his boyhood he made mechanical toys, clocks, and sundials; he was skilled with his hands, possessing, like so many scientists of the first rank, that priceless gift of "handicraft"; and he habitually noted down, from his schooldays, interesting chemical "recipes" that he met with. His interest in chemistry probably began when he was boarding at the house of the apothecary Clark during his schooldays in Grantham.

This early interest in chemistry continued after Newton went to Cambridge. In 1669, the year in which he became Lucasian Professor, he bought chemicals, flasks, furnaces, and a *Theatrum chemicum*. About this time, too, he experimented on the production of alloys suitable for use in the mirrors of the reflecting telescope that he had designed. He fitted up one of his rooms in Trinity as a chemical laboratory and devoted much time to study and experiment. When his friend Aston was leaving on a foreign tour in May 1669 and sought his advice, Newton advised him to observe, among other things, the methods of mining, smelting, and refining; to take note of any transmutations he might meet with; to try to find out whether "at Schemnitium in Hungary . . . they change iron into copper by dissolving it in a vitriolate water"; and to investigate whether the waters of certain rivers in the mining regions of Central Europe contained any gold, and whether this was recovered by means of mercury.

So Newton maintained his interest in chemistry, notably in the period when he was composing the *Principia*. Wearied with the burden of that supreme book, he seems to have turned to chemical experiments as a relaxation. Humphrey Newton, his assistant at that time, says:

"About 6 weeks at spring, and 6 at the fall, the fire in the elaboratory scarcely went out, which was well furnished with chemical materials as bodies, receivers, heads, crucibles, etc., which was made very

little use of, the crucibles excepted, in which he fused his metals; he would sometimes, tho' very seldom, look into an old mouldy book which lay in his elaboratory, I think it was titled Agricola de Metallis, the transmuting of metals being his chief design, for which purpose antimony was a great ingredient."

Master Humphrey was not well informed. No one would consult Agricola on the transmuting of metals; that noble old metallurgist was not fond of alchemists and dowsers and such-like. And Master Humphrey, and others who have whispered so knowingly to us after perusing his words that the great Newton himself was an alchemist, might have recalled that antimony was used in alloys for metal printing types long before Newton's day. It seems that antimony is a suspicious substance for men of reputation to touch; perhaps it still has some lingering association with Jezebel.

With regard to theory, Newton was a follower of the Netherlands chemist, Johann Baptista van Helmont (1577 or 1580-1644), who discovered the materiality of gases and revived the theory, first propounded by Thales of Miletus (c. 624-565 B.C.), that all substances were produced from water. Boyle, though a great admirer of van Helmont, was sceptical about this theory, as about most things; but Boyle's corpuscular explanations of chemical phenomena deeply influenced Newton. Boyle was successfully using not, of course, our present atomic theory, but the Greek atomic theory, which saw in the various substances in Nature so many aggregates of differing numbers and arrangements of ultimate identical "uncuttables" or atoms. In this view, all atoms were qualitatively the same; and therefore matter was transmutable. It is in this sense of transmutability that Newton was an "alchemist," and so also is the modern atomic physicist. But both are worlds away from the Philosophers' Stone and the Elixir of Life. As for the wide evidence we have of Newton's copying of extracts from alchemical authors, the significance of this has been over-emphasized. Boyle did likewise, and so have others. Such books were often rare. Moreover, Newton copied from other books as well. And his library contained chemical works other than those of alchemists. Alchemical books often gave valuable practical information on the properties of the metals.

Newton took his chemistry from van Helmont and Boyle. His

world was a world of atoms and void, in which all substances were produced from water, a world of flux that would have delighted the soul of Herakleitos. Let us consider some of its interesting detail. Newton's contemporaries and predecessors had discussed the apparent dissipation of matter from the tails of comets. Newton thought that gravity would presently attract such matter towards the planets, where it would replenish water lost in evaporation and in conversion into earth:

"... for as the seas are absolutely necessary to the constitution of our earth, that from them, the sun, by its heat, may exhale a sufficient quantity of vapours, which, being gathered together into clouds, may drop down in rain, for watering of the earth, and for the production and nourishment of vegetables; or, being condensed with cold on the tops of mountains (as some philosophers with reason judge), may run down in springs and rivers; so for the conservation of the seas, and fluids of the planets, comets seem to be required, that, from their exhalations and vapours condensed, the wastes of the planetary fluids spent upon vegetation and putrefaction, and converted into dry earth, may be continually supplied and made up; for all vegetables entirely derive their growth from fluids, and afterwards, in great measure, are turned into dry earth by putrefaction; and a sort of slime is always found to settle at the bottom of putrefied fluids; and hence it is that the bulk of the solid earth is continually increased; and the fluids, if they are not supplied from without, must be a continual decrease, and quite fail at last. I suspect, moreover, that it is chiefly from the comets that spirit comes, which is indeed the smallest but the most subtle and useful part of our air, and so much required to sustain the life of all things with us." (*Principia*, III, XLI, xxi.)

The last sentence links Newton's views with those of Boyle, Hooke, and Mayow on the existence of a vital constituent in the atmosphere, isolated by Priestley long afterwards and named "oxygen" by Lavoisier.

In 1692 Newton drew up a paper entitled *De natura acidorum*, apparently an unfinished composition dealing with chemical affinity. It was published in 1710; but it was in the queries appended to his *Opticks* that Newton approached this problem more closely, and to these famous questions we shall now turn.

According to Newton light was material, and it seemed to him that bodies could be changed into light and light into bodies. Indeed, this appeared to him "very conformable to the Course of Nature, which seems delighted with Transmutations." The last clause of Newton's sentence has often been torn from its context as evidence of his being an alchemist! He reminded his readers at this point that water by repeated distillation changed into earth—a scientific "fact" unrefuted until the work of Lavoisier, long afterwards. A sort of air may be obtained, said Newton, by heating water; and several sorts of air may be obtained when dense bodies, i.e. solids, are rarefied by "fermentation," a process which may be reversed so as to make the air thus produced revert by another fermentation to its first state. "And among such various and strange Transmutations," he asked, "why may not Nature change Bodies into Light, and Light into Bodies?"

But chemists will always find most interest in Newton's speculations on the forces concerned in chemical change. He writes:

"Have not the small Particles of Bodies certain Powers, Virtues, or Forces, by which they act at a distance, not only upon the Rays of Light for reflecting, refracting, and inflecting them, but also upon one another for producing a great Part of the Phaenomena of Nature? For it's well known, that Bodies act one upon another by the Attractions of Gravity, Magnetism, and Electricity; and these Instances shew the Tenor and Course of Nature, and make it not improbable but that there may be more atractive Powers than these. For Nature is very consonant and conformable to her self." (*Opticks*, 4th edition, 350-1,)

The deliquescence of "salt of tartar" (potassium carbonate) Newton ascribed to an attraction between its particles and those of water vapour in the air, while salts that did not deliquesce lacked such attraction; the quantitative limit to the amount of water taken up showed that the attractive force of the salt had been "satiated." The development of heat on the mixing of oil of vitriol and water argued a great motion and a violent coalescence of the particles of these liquors. The action of "spirit of vitriol" on salt and on saltpetre, whereby the "spirits" of these salts ("spirit of salt" and "spirit of nitre") were produced, while the acid part of the "spirit of vitriol"

remained behind, suggested "that the fix'd Alcaly of the Salt attracts the acid Spirit of the Vitriol more strongly than its own Spirit, and not being able to hold them both, lets go its own." The strengths of these attractions between various substances varied, and so the vigour of chemical change ranged from slow ebullition and gentle heat to violent explosion and the heat of fire and flame.

In precipitations of acid solutions of the metals by means of alkalis, it appeared that the acid particles were attracted more strongly by the alkali than by the metal, and so they went from the metal to the alkali. A similar explanation suggests itself for the deposition of copper from an acid solution of that metal by means of iron. This last example and its explanation remind us that Newton had mentioned it to Aston in 1669 as worthy of his inquiry; what it also suggests is that it can hardly be regarded as evidence for Newton's devotion to alchemy.

It is clear that Newton was greatly interested in the problem of chemical attractions and forces. He considered that the particles of a salt in solution diffused evenly through the solvent as though they were moved from one another by a repulsive force, or, at least, that they attracted the water more strongly than one another. Yet, on evaporation of the solution, these same particles concreted in regular figures, which seemed to argue that before this concretion they were arranged in the solvent "at equal distances in rank and file" under the action of "some Power which at equal distances is equal, at unequal distances unequal." He followed this to its logical conclusion of polarity in the particles:

"For by such a Power they will range themselves uniformly, and without it they will float irregularly, and come together as irregularly. And since the Particles of Island-Crystal act all the same way upon the Rays of Light for causing the unusual Refraction, may it not be supposed that in the Formation of this Crystal, the Particles not only ranged themselves in rank and file for concreting in regular Figures, but also by some kind of polar Virtue turned their homogeneal Sides the same way?" (*Ibid.*, 363.)

Newton was prepared to infer that the cohesion of the particles of solids was due to an attractive force, which was very strong in immediate contact, produced chemical action at short distances, and did not extend far from the particles.

Since all bodies appeared to be composed of hard impenetrable particles, some attractive force was necessary for cohesion. The concretion of particle upon particle produced larger particles with weaker powers of attraction, and so on, until the particles become of those dimensions at which chemical changes occurred and where, by further cohesion, bodies of sensible magnitude were produced. There was likewise a repulsive force, as already noted. So, said Newton:

"Nature will be very conformable to her self and very simple, performing all the great Motions of the heavenly Bodies by the Attraction of Gravity which intercedes those Bodies, and almost all the small ones of their Particles by some other attractive and repelling Powers which intercede the Particles." (*Ibid.*, 372.)

But he, who had achieved the unique triumph of formulating the mathematical law of gravitational attraction, was unable to wrest from Nature the laws of chemical attraction and to arrive at any corresponding simple numerical relationship. The problem is indeed one of far greater difficulty, since the attraction varies with the chemical nature of every reactant instead of with mere mass. Even to-day it would be bold to claim that progress on this problem reveals anything remarkably satisfying. Yet it might well be that here was the great object of Newton's chemical speculations and researches, and that here in the microcosm of chemistry he sought to parallel his discoveries in the macrocosm of mechanics.

THE ORIGIN OF THE LUNAR FEATURES

By R. A. McIntosh

THE chief disability suffered by the meteoric theory of the formation of the lunar features is that it has been developed in advance of our knowledge of the behaviour of meteors. The first suggestion of bombardment forming the lunar craters was made, in fact, several hundred years before scientists admitted that stones fell from the sky (Robert Hooke—London 1665).

A further disability, and a very annoying one to protagonists of both theories, is that mentioned by MacDonald (This Journal, vol. 36, p. 159, Apr. 1942), the difficulty of applying tests which will differentiate between the volcanic and meteoric theories.

The meteoric theory was first developed by Proctor (1873), while others who added to or varied its form were Gilbert (1892), Shaler (1903) and See (1910). Until very recent years, however, the general form of the theory has been that unusually large meteors, raining on the moon in exceptional numbers while its surface was still plastic, had produced the observed features.

When, in 1924, Gifford (*N.Z. Journ. Sci. & Tech.*, vol. 7, p. 129, 1924, and vol. 11, p. 319, 1930)* first drew attention to the great kinetic energy developed in a collision between a meteorite and the moon he was able to suggest a reasonable answer to the three principal arguments levelled against the earlier form of the theory, namely, the necessity for a terrific bombardment of the moon by meteorites of vast dimensions, the absence of similar craters on the earth (which could not have escaped sharing in the bombardment), and the belief that meteorites striking obliquely could not produce circular craters.

No exact mathematical formula can be composed to describe the process during impact, for we do not know whether the meteorite upon collision would be instantaneously exploded or would survive for the fraction of a second, enabling the observed depths of penetration to be achieved. The nature of terrestrial meteoritic craters, however, indicates that Gifford's assumptions are substantially correct.

*Reprinted in this Journal, vol. 25, p. 70, Feb. 1931.

Subject to present limitations to our knowledge, it appears that the meteoritic impact theory provides a satisfactory and consistent explanation of the origin of the lunar features, while the objections to the other theories outweigh any possible points they may score.

For the plastic lunar surface necessary to the earlier theories Gifford was able to postulate a solid crust, but, as Dr. Spencer pointed out (*Nature*, vol. 139, p. 655, 1937), a further objection then arose, for, if the new theory were correct, the appearance of new lunar craters should have been noticed during the period in which the moon's surface was mapped.

A point which does not seem to have concerned the theorists is the depth to which a meteorite could penetrate before the explosion took place. There is no way of ascertaining this, but the fact that craters exist, both on the earth and moon, has led supporters of the impact theory to believe that such penetration is possible.

With a slight modification, which I here advance, the meteoric theory becomes a consistent explanation of the appearance of the lunar surface. If Gifford's reasoning is applied, not to the solid moon we know to-day, but to the softer, plastic moon much earlier in the history of our satellite, while it is claimed that meteorites cannot penetrate to any great depth through the present solid crust, the absence of new craters is readily explainable.

Before the moon had cooled sufficiently to possess a solid crust the meteorites colliding with it, in my view, were able to effect the maximum penetration into the plastic surface before exploding, and therefore in exploding removed a larger quantity of material and produced a larger circular depression than would have been possible on a more solid surface. Thus, first of all, the outlines of the maria may have been formed.

As the moon cooled its surface contracted, fissures formed, and through these the interior magma welled to cover the lower-lying areas and the circular depressions, thus forming the level surfaces of the maria and the walled plains, obliterating in the process the central peaks of the latter objects (generally of much less altitude than the rims).

Many evidences of this flowing of the magma can be found on the lunar surface. A typical example of the obliteration of earlier

detail can be seen east of the Apennines, where hills and crater walls have been reduced and broken down by the flow. One small patch of the original high land stands surrounded as if by flood waters. Many other examples are revealed in the books written by various selenographers, while an evidence of the once-plastic condition of the maria mentioned by Goodacre ("The Moon," p. 20) is that the numerous clefts fringing the maria appear to him to have resulted from the cooling and consequent shrinking of the surface of the maria.

The statistical evidence in support of the view that the maria were formed at a later stage than the continental areas (Young, *Journ. B.A.A.*, vol. 50, p. 305, July 1940) is strong. Unlike the other types of crater, ante-mare objects show no great increase in frequency for the smaller objects, a result to be expected since these smaller objects (with lower walls) would have had little chance of surviving the engulfing flood of lava. The percentage of objects with central mountains was also explained by Young as a result to be expected if many of the ante-mare craters had been destroyed. The deficiency of central mountains in ante-mare craters, Young points out, may arise from the destructive effects of the lava flood. Goodacre, in "The Moon," has published a lunar reconstruction showing numerous ruined rings almost completely obliterated by the maria which are now visible only as haloes of light near the full moon phase.

Statistical studies revealing the non-randomness of the distribution of lunar craters have little bearing on the efficiency of my modification of the meteoric theory, for the formation of the maria after the creation of most of the continental craters, the obliterating effect of the lava, and its subsequent relatively rapid cooling (because of its shallowness) must have played havoc with the laws of probability in application to the observed distribution of lunar craters.

Perhaps the most significant feature of Young's statistical researches, however, is the evidence he adduces showing that all these objects, great or small, whether continental or post-mare in nature, arose from a similar agency and can be explained only by a comprehensive theory, and not by the give and take methods of recent trends of the ever-changing volcanic theory, the supporters of

which have been willing to say to the meteoriticists: "You can take the large craters and we'll keep the small ones."

As the moon's crust cooled and became more solid, I suggest, the meteorites were unable to penetrate as deeply as before, with the result that craters became progressively smaller in diameter, so that (within the limits due to the varying kinetic energy of the individual meteorites upon collision and differentiating between continental and post-mare objects) the size of a lunar crater should be approximately proportional to its age. Thus the significance of the relation between the diameters and depths of lunar craters, published in my earlier paper (This JOURNAL, vol. 35, p. 361, Nov. 1941) is revealed.

It appears that the material of the maria was never so plastic as that composing the continental regions in their fluid state, for no really large craters exist on the maria.

Small craters are frequently found superimposed on larger objects, but the reverse case is much rarer. Goodacre, a prominent selenographer, has been convinced, from his intimate knowledge of the lunar surface, that the larger objects appear to be the oldest ("Splendour of the Heavens," p. 286). Young has found from 52 cases in a selected area that the number of occasions in which the smaller crater overlapped the larger could be expected to be 27.3, leaving 24.7 cases where the opposite could be expected. Actually the observed proportions were 35 to 17, a feature which supports my belief in the declining size of craters as the lunar crust, solidified.

The evidence of dust on the lunar surface, revealed in researches on the reflectivity of the moon and the polarization of the reflected light (Dr. Wylie, *Popular Astronomy*, vol. 50, p. 268, May 1942) are by no means antagonistic to the meteoric theory, nor to my suggested amendment of it, for the millions of meteorites which must have been shattered on or close to the surface since the lunar crust solidified must have built up an appreciable layer of dust over the entire globe.

The small total of craters on the moon (Fauth's count, excluding rim objects, gives a total of 2154 objects) indicates that they cannot have been formed continuously throughout all stages of the moon's history. If only one crater-forming meteorite were to strike the moon each year (and that is a very modest estimate for a globe

unprotected by an atmosphere) there would still be millions of craters instead of the few thousand actually observed.

A possible explanation of the occasional presence of central peaks is indicated from the fact that these features occur generally in the larger craters. It may have been that a certain degree of plasticity was essential to the formation of these peaks, and that, as the moon slowly solidified and the craters consequently became progressively smaller, a stage was reached where the material was too nearly solid to permit the formation of further central peaks.

Finally, at the risk of disturbing the ashes of the Linne controversy, is it not possible that the moderate crater described and mapped by the early selenographers may have been subjected in telescopic times to a direct hit by a large meteorite which, shattering itself against the now-solid surface of the moon, wrapped the celebrated object in the halo of white dust which is its present-day appearance?

Private Observatory,
1 Melford Street,
Auckland W.1,
New Zealand.
28 July, 1942.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

Newton Tercentenary Celebrations

The three-hundredth anniversary of the birth of Sir Isaac Newton has been fairly widely celebrated even in these trying times. The University of Toronto commemorated the birth of our greatest scientist at a quiet ceremony in the McLennan Laboratory on January 6. This marked the formal presentation to the University of a copy of the third edition of Newton's *Philosophiae Naturalis Principia Mathematica* by the Toronto merchant and philanthropist, Dr. Sigmund Samuel. Dr. H. J. Cody, the president of the University, accepted the book on behalf of the University and passed it over to Dr. E. F. Burton, head of the Department of Physics, who will act as custodian.

The *Principia* was first published in 1687. Edmund Halley, the second Astronomer Royal, had urged Newton to write the book, had superintended the printing and met the expense. Halley wrote a poem dedicated to Newton's work which was prefixed to the text of the work. The second edition of the *Principia* appeared in 1713 and was edited by the young mathematician Roger Coates, and seen through the press by the classical scholar Richard Bentley. The third edition, published in 1726, was the last to appear in Newton's lifetime. The editor in this case was Henry Pemberton, a physician and scientist.

The gift copy of the *Principia* has been placed in the foyer at the entrance to the physics laboratory along with an Italian marble bust of Newton, another gift from Dr. Samuel. The bust was executed by Dame Dora Clarke after the original in Trinity College library in Cambridge.

In England Newton's birth has been commemorated by a number of scientific bodies. The two-hundredth anniversary meeting of the Royal Society on November 30 was given over to an appreciation of Newton's work. The president, Sir Henry Dale, gave an address on Newton. He reminded the members "that while Newton's great discoveries belong to the world, they came to publication through the Royal Society, and that Newton occupied its presidential chair

for the last twenty-four years of his long life. . . . There can be no doubt . . . that the wide fame of his achievements, and the respect and admiration in which he was everywhere held, did much, at a critical period of its history, to establish the prestige of this society in the eyes of the world."

Sir Henry Dale announced that the house in which Newton was born and its garden are to be preserved as a national memorial. The Pilgrim Trust will defray the cost of the purchase from its present owner, Major E. B. Turnor, who has agreed to dispose of the property for less than its commercial value.

Other lectures followed: Prof. E. N. da C. Andrade spoke on "Newton and the Science of his Age," Lord Rayleigh on "Newton as an Experimenter" and Sir James Jeans on "Newton and the Science of To-Day." The manuscript of the first edition of the *Principia* and other Newtoniana were exhibited in the library of the Royal Institution.

An exhibition of books connected with Newton was opened in the Wigan Central Library on November 30 by Mr. Leonard Stanley Newton, a descendant of the Woolsthorpe family. It includes copies of most of Newton's published scientific papers and books and many works of contemporary authors bearing on Newton's discoveries.

The Physical Society commemorated the tercentenary of Newton's birth by a lecture by Prof. Andrade on Newton held in the Cavendish Laboratory in Cambridge on December 9. On the same night lectures at the Institute of Physics were given by Dr. H. Lowery on "Life of Newton" and by Dr. H. F. Buckley on "Some Historical Aspects of Newton's Published Works."

A celebration was held on December 13 at Grantham near Woolsthorpe-by-Colsterworth where Newton was born. A laurel wreath was laid at the foot of Grantham's statue of the scientist by J. H. Foster, the head boy of King's School; Newton was head boy at King's School before entering Cambridge. The ornamental railings which were formerly around the statue have been taken down to be used for war purposes. On December 20 Sir Henry Dale placed a wreath on Newton's grave in Westminster Abbey.

If times had been normal this notable anniversary of Newton's birth would have been more widely celebrated throughout the world.

Newton's discoveries belong to the world, and the anniversary might well have been marked by great international gatherings.

R. J. N.

Nova Puppis 1942

A bright new star was discovered in the constellation Puppis (part of Argo) on November 10. From the Announcement Cards of Harvard College Observatory the following information is taken:

No. 637, Nov. 10, 1942.—A nova "nearly first magnitude" in R.A. 8 h. 9.5 m., Dec. 35° 12′ S. was discovered by Professor B. H. Dawson of the Observatory at La Plata.

No. 638, Nov. 12.—Dr. W. W. Morgan of the Yerkes Observatory on Nov. 11 observed Nova Puppis "visual magnitude about 0.5. Spectrum in photographic region contains very broad absorption lines of H and Fe II. The strongest lines have relatively faint emission components.

On Nov. 12 the visual magnitude was 0.6 according to Mr. Leon Campbell of Harvard Observatory.

No. 639, Nov. 14.—The nova was found independently by A. D. Maxwell at Ann Arbor, the morning of Nov. 11, but too late to obtain spectra. Estimated magnitude about 1.0. On the morning of Nov. 12 Maxwell and McLaughlin observed it. Estimated magnitude 0.5.

"The spectrum shows strong hazy emission of hydrogen, and conspicuous hazy emission of Fe II, and OI 6155, with centres approximately undisplaced. Absorption spectrum is very diffuse, strong hydrogen and Fe II, and conspicuous Ti II, Mg II, OI, and Si II pair in the red. Hydrogen is wide and just suspected double. Absorption displacements are discordant. Estimates of velocity are: hydrogen, −1100 km./sec.; Fe II and Ti II, −900; Mg II, −750.

The diffuseness of both absorption and emission, and the discordant velocities recall the case of Nova Herculis before maximum, and arouse a suspicion that the star is still increasing."

No. 640, Nov. 16.—Telegrams from Zurich, and from Copenhagen via Lund report the independent discovery of Nova Puppis by Finsler.

The visual magnitude this morning was 2.4.

No. 641, Dec. 5.—Mr. Campbell reports that the nova has steadily dim' 'shed in brightness from about magnitude 0.5 on the morning of Nov. 12 to ma ude 5.5 on Nov. 30. The diminution between Nov. 12 and Nov. 17 was 2.. ni- tudes; between Nov. 17 and Nov. 22, 1.8 magnitudes; and between Nov. 1 d Nov. 29 1.1 magnitudes.

We hope to have a general statement regarding the star in a later issue.

C. A. C.

Newton's Reflecting Telescope

Newton was born on Christmas Day, 1642—three hundred years ago. Among his manual accomplishments was the construction of a reflecting telescope. The following note referring to this is extracted from *The Griffith Observer* for October, 1942:—

Newton's work with the prism showed that a serious defect of the refracting telescope was caused by chromatic aberration of the lens. Two thin prisms put base to base resemble a double convex lens both in appearance and behaviour. Light is bent toward the thickest part and is separated into colours in both cases. In a prism this separation into colours serves the useful purpose of making a spectrum. However, when the lens does the same thing it blurs the image, each colour forming an image in a slightly different place.

After performing one experiment Newton came to the erroneous conclusion that refraction, or the bending of light, and dispersion, or the separation of the colours, are exactly proportional in all substances. This led him to despair of improving refracting telescopes, and he turned his attention to reflectors. He examined a drawing made by James Gregory in 1663, who proposed an instrument that made use of a concave mirror instead of a lens to form the image. Gregory's drawing showed a perforated parabolic mirror with an elliptical mirror forward of the focus returning an image to the eyepiece through the perforation. Such an arrangement would overcome chromatic aberration and it had other advantages, but no one at the time could produce mirrors with curvatures sufficiently exact.

Newton simplified this kind of telescope by replacing the second curved mirror by a flat one placed a little inside the focus and inclined at 45 degrees. This simple way of getting the image outside the tube is still used to-day in what is known as the Newtonian arrangement. He constructed with his own hands the first reflecting telescope, using speculum metal for the mirror. He made a telescope in 1671 and presented it to the Royal Society, which still has it. It is really only a model, about 15 inches high and the mirror is one inch in diameter. It was not of much use as an astronomical instrument, probably because he made the curvature of the mirror spherical instead of paraboloidal. A spherical mirror does not bring all the rays to one focus, but the other kind does.

About half a century elapsed (after 1671) before the first useful reflecting telescope was made in 1722 by John Hadley, who also invented the sextant. After Newton's death a paper was found among his belongings showing that he had invented the sextant, but he did nothing more than describe the device.

C.A.C.

MEETINGS OF THE SOCIETY

AT WINNIPEG

November 12, 1942.—The regular meeting of the Winnipeg Centre was held in theatre "F" of the University of Manitoba, at 8.15 p.m. The president, Mr. L. W. Koser, was in the chair.

The lecture was given by one of the Centre's past presidents, Flying Officer D. R. P. Coats. He talked about the making of an amateur telescope.

As F. O. Coats has made several telescopes, he was well qualified to speak on the subject. He had on exhibition actual apparatus to illustrate every stage of the process and many models of telescope mountings.

He said that few amateurs tried to make refractor telescopes as several accurately figured lenses are required. Reflector telescopes need only one mirror to be figured.

A popular size telescope requires two discs of plate glass each 6 inches across and 1 inch thick. One piece is stuck with pitch to a piece of wood and is the "tool". A handle is stuck to the other piece which is to become the "mirror".

Now water and carborundum (size 80) is sprinkled on the tool and the mirror is moved back and forth across it. At the same time the mirror is given a slight rotary motion on each stroke and the amateur telescope maker gradually moves around the stand holding the tool. By these three motions the tool becomes convex and the mirror concave. The grit is removed with water and gradually changed to finer sizes until the depression is 1/20 inch.

Then the test for a perfect spherical curve has to be made. This is done with a flashlight at the centre of curvature. More careful grinding for perhaps thirty minutes, must now be done. The grit has to be of six different grades and each must be thoroughly washed off before using the next finer grade. After this pitch is put on the surface of the tool and marked in squares. A slush of rouge and water is put on the mirror and polishing is done. This should result in the mirror becoming a parabola.

As the surface approaches a parabola it may be tested optically by means of a pin-point of light and a movable razor-blade. An experienced observer can judge the shape from the pattern of the shadows on the mirror.

The mirror may now be silvered and finally mounted in a tube. Many models of mountings were discussed, including (1) altitude and azimuth, and (2) equatorial, of the English, Yoke, German and Fork types. The lecture was closed with slides of actual work and materials used.

Many questions attested the interest of the audience in this very enlightening and entertaining demonstration.

OLIVE A. ARMSTRONG.

December 10, 1942.—A regular meeting of the Society was held at 8.15 p.m. at the University of Manitoba. As the president, Mr. L. W. Koser, gave the evening's lecture, the chair was taken by Mr. L. J. Crocker.

Mr. Koser's topic was "Mapping the Stars." He was well qualified to speak of this as he had drafted several large planispheres which many members had seen and used. He began by explaining that positions upon the surface of the earth are given in latitude and longitude. These are similar to declination and right ascension in the sky. Imagine the poles and equator of the earth to be extended outwards to the sky. Declination is + if north of the equator and — if south of the equator. Right ascension is more difficult to visualize, but the principal meridian is a line drawn from North Celestial Pole to the place where the ecliptic (sun's apparent path in the sky) crosses the equator on its northward journey. This point is called the Vernal Equinox or the First Point of Aries. The line passes through Cassiopeia and cuts off the two north-east stars. This line is known as the equinoctial colure or hour circle 0h. From this line the heavens are divided into 360° or 24 hours by hour circles 15° or 1h. apart. These hour circles are numbered in the heavens going eastward, and right ascension is measured from the equinoctial colure.

Following this somewhat lengthy explanation Mr. Koser used one of his maps to locate these stars: Alpha Andromedae, Alpha Tauri, Alpha and Beta Orionis, Alpha Canis Majoris, Alpha Canis Minoris, Alpha Aurigae and Algol.

Interesting facts such as apparent magnitude, types of stars and their temperatures, proper motions, parallax, distance in light-years and parsecs, absolute magnitude and radial velocity were given for each star.

Much discussion closed a very interesting evening.

Olive A. Armstrong.

AT VICTORIA

October 21, 1942.—The first meeting of the fall and spring session of the Victoria Centre was held at Victoria College. Mr. O. M. Prentice, the vice-president, opened the meeting at 8.15 p.m.

Dr. W. P. Walker, Mr. G. Darimont and Mrs. K. Maltwood were elected members by acclamation.

The lecture of the evening was given by the president, Dr. R. M. Petrie, his subject being "The Size of the Universe". The lecturer sketched the course of the Milky Way, beginning in Sagittarius, through Scorpius, Aquila, Cygnus and Cepheus, and by means of the lantern an unfolding of this region was portrayed as a continuous strip, giving a new light on the density and extent of the Galaxy in this hemisphere. He proceeded to explain why the star population was greater in Sagittarius than in Taurus or Orion.

The Globular Clusters were shown and it was explained how they define a near limit to the extent of the galaxy in any direction in which they are found. As these clusters contain many Cepheid variables their distance can be

computed, hence the limit. It can be shown that these clusters are not equally distant from our sun, hence the universe is not symmetrical in respect to our sun.

Following this introduction, the speaker discussed the dynamical method of probing the universe, based upon studies of stellar motions. It was shown that observations of the proper motions and radial velocities of the more distant stars gave clear evidence that our universe is in rotation about a central nucleus located in the direction of Sagittarius, and distant about 30,000 light-years. The "orbital" speed of our sun is found to be 275 km./sec., and the time required for one revolution is 200 million years.

The observations lead to a determination of the size and mass of the galaxy. The diameter is found to be about 100,000 light years—somewhat larger than, but comparable in size to, other external systems and the total mass is equivalent to 160 billion suns. Of this mass at least one-half is composed of interstellar dust and gas.

R. PETERS, *Recorder.*

November 18, 1942.—The regular meeting was called to order by the president, Dr. R. M. Petrie, at 8.20 p.m. Two new members, K. Maltwood and Dr. J. S. Stevenson were introduced to the Society; and the librarian, Miss Y. Langworthy, especially recommended the periodicals, *Popular Astronomy* and *Sky and Telescope* for the reading of members.

The speaker of the evening, Dr. G. M. Volkoff, professor of physics at the University of British Columbia, was introduced by Dr. Andrew McKellar as an authority on atomic theory. He chose for his subject "Sources of Stellar Energy". In the olden days, Dr. Volkoff said, there was some question about the relative importance of the sun and moon—for the moon gave us light by night and the sun shone by day. We have progressed far since then, and one of our most interesting problems to-day is, What makes the sun and the star shine? We know that the sun liberates 2 ergs/gm./sec. and if made of coal, it could last about 5000 years; and even the rocks tell us that it has lasted at least 10^{10}, or ten thousand million, years. Kelvin and Helmholtz studied the source of this energy about 1880; various hypotheses were suggested:—meteorites falling into the sun, contraction of its radius, or radioactivity but none could supply enough energy. In 1905 Einstein first gave a clue to a better source when he proposed a relation between matter and energy. Eddington studied the internal constitution of the stars and Aston made many experiments on isotopes and their atomic weights. Finally within the past five years, Bethe, Gamow and others were able to find evidence that matter was actually annihilated and that hydrogen was turned into helium in a reaction with carbon and nitrogen. In the sun, hydrogen is so abundant that the energy thus liberated would last 10^{11} or more years, which is sufficient according to present estimates.

Following this interesting lecture, the members questioned Dr. Volkoff about possibilities of this new theory. A vote of thanks to the speaker was moved by Dr. C. S. Beals and heartily acclaimed by the forty members present.

K. O. WRIGHT, *for Recorder.*

December 16, 1942.—The December meeting took the form of the Annual Dinner held at the Y.W.C.A. at 6.30 p.m. There were 71 members and friends present. An excellent musical programme consisting of vocal solos by Mr. Sidney Chiverall and Master Keith Littler, accompanied at the piano by Mrs. C. S. Beals, who later gave two solos, contributed to the enjoyment of the meeting.

A toast to the King was proposed by the President, Dr. R. M. Petrie. After the dinner a short business period was conducted. Annual reports were read by the secretary-treasurer, Mrs. M. V. Yarwood, in which it was stated that eleven new members had been added during the year, bringing the membership to 105; the report of the telescope-making section was read by Mr. Gordon Shaw; special mention was made of the 8-inch telescope presented to the Society by H. A. Reid and the observing site made possible by H. D. Day. Mr. Robert Peters read the report of the annual dinner, 1941, and Miss Y. Langworthy, the librarian, reported that more books had been borrowed from the Society's library this year. A new book-case is now under construction. Mrs. K. C. Maltwood donated two books to the library and Dr. R. M. Petrie donated some pamphlets on the life of Dr. J. S. Plaskett. Mr. R. Peters moved that a letter of best wishes be sent to Miss Hailstone, the former librarian of the Society. It was proposed that a special vote of congratulation be sent to Mr. Boyd Brydon, who was awarded the Chant Medal for outstanding contributions to the Society, and who was unable to be present. A special welcome was extended by the president to Mr. McDonald of the Vancouver Centre. The meeting stood in silent tribute to Capt. Wm. Everall and J. D. Pomeroy, who died during the year.

The annual election of officers was conducted. Mr. O. M. Prentice was chosen president for 1943. Dr. R. M. Petrie, the retiring president, thanked the members of the council for their support during the past year, which had been a very successful one for the Society. He also mentioned the great help the past-presidents had been. Mr. Prentice spoke briefly thanking Dr. Petrie for his able and valued services. Other incoming officers besides Mr. Prentice were: Robert Peters, honorary president; Dr. Andrew McKellar, first vice-president; Dr. K. O. Wright, second vice-president; Mrs. M. V. Yarwood, secretary-treasurer; Miss E. Walker, recorder; Miss Y. Langworthy, librarian; Mr. W. Hobday, director of the telescope-making section; and a council of six including, Messrs. G. L. Darimont, H. D. Day, G. T. Freeman, J. Moulson, M. Trueman, and Dr. W. P. Walker. Mr. Shaw proposed the vote of thanks to the musical artists and Mr. J. Moulson thanked the Victoria *Daily Times* and the *Daily Colonist*, represented by Mr. Sandham Graves, in a vote to the press. Three new members were welcomed:—Canon H. V. Hitchcox, T. J. Lokier and R. C. Sairall.

The main event of the evening was the most interesting and instructive talk by Dr. J. A. Pearce, Director of the Dominion Astrophysical Observatory, on the first Inter-American Science Congress held at Puebla, Mexico, in February of this year. Dr. Pearce attended the meeting on the part of Canada and pre-

sented a paper there. It was a most important occasion in the educational programme of Mexico. President Camacho of Mexico dedicated the new Astrophysical Observatory at Tonanzintla, Puebla. There were 27 astronomers, physicists and geologists from Canada and the United States and about a dozen Latin-American delegates. The President congratulated them on the professional fervour they showed in coming, and stressed the importance of hemispheric unity in defence, education and research. In all, 33 addresses were given. Since the new observatory at Tonanzintla alone among modern observatories commands a view of the whole of the Milky Way, most of the papers dealt with the structure and constitution of the Galaxy, and its relation to other galaxies. In many original slides and photographs, Dr. Pearce exhibited views of the ancient pyramids to the sun and moon, sacrificial stones of the Aztecs and Toltecs and the beautiful cathedrals and temples of the superseding Spanish culture. He also showed a photograph of the special set of postage stamps that was issued depicting a solar eclipse, the Ring Nebula in Lyra, the Horse-Head Nebula in Orion and other stellar objects. His address was much appreciated and led to a warm vote of thanks proposed by Mr. M. C. Truęman.

E. WALKER, *Recorder.*

AT TORONTO

October 13, 1942.—The Society met in the McLennan Laboratory, University of Toronto, at 8.00 p.m., Dr. D. W. Best in the chair. Minutes of the previous meeting, held on April 14, 1942, were taken as read.

Professor A. F. C. Stevenson, of the department of applied mathematics, University of Toronto, addressed the Society on "Recent Developments in the Quantum Theory and their Relation to Astronomy." Because of the publicity given it, the theory of relativity had attracted the attention of the intelligent general public but the quantum theory, equally imporant to the physicist and astrophysicist, was not so familiar to the layman, Professor Stevenson said.

The idea of the energy quantum, while it seemed radical at first, soon came to be generally acceptable to physicists. Phenomena of radiation, absorption and energy transfer which seemed impossible to explain by the older or "classical" theory led to Planck's suggestion that electrons did not radiate in a continuous manner as required by Maxwell's electromagnetic theory. Planck suggested that energy existed in bundles or "quanta" proportional to the frequency of the radiation. This new idea, although in apparent contradiction to the wave theory of light, not only enabled Planck to derive a rational radiation law but also led Einstein to a simple explanation of the photoelectric effect and Bohr to his explanation of the origin of spectra.

The resulting law of black-body radiation introduced a new constant, known as Planck's constant or h. According to Bohr's theory, an electron in a given orbit represents a given energy state. When an atom absorbs energy from radiation incident upon it, one of its electrons is moved to a higher energy orbit,

farther from the nucleus. This energy may only be absorbed in quanta: hf, $2hf$, $3hf$, etc., where f is the frequency, to put the electron in some allowable energy state. An atom becomes "excited" if the electron jumps to a higher orbit, or is "ionized" if the electron is thrown clear. In either case the atom tends to recover equilibrium and when the electron returns to its original orbit a quantum of energy is released. Both the absorption and release of the energy take place in abrupt jumps or quantum transitions. When the electron drops from a higher to a lower orbit of energy, a light quantum is given out, viz: $E_1 - E_2 = hf$.

Turning to the more modern quantum mechanics which was an outgrowth of the older ideas of Planck, Bohr and others, Prof. Stevenson said: "The most remarkable thing about quantum mechanics as we now view it is the concept of probability that rules everything. It can only be stated that an electron is probably within a certain area, moving within certain velocity limits, at a certain time. According to the classical theory, if it could be determined what every particle in the universe was doing at a certain time and if we could work out the mathematical equations involved, it would be possible in principle to determine exactly the beginning and end of the universe and all the states between. Of course this would all be impossible in practice. With the quantum theory, however, such a determination would not even be possible in principle because the initial state of the universe is not known with certainty. But with the new idea of quantum mechanics we can calculate many things which were impossible with the classical mechanics. It is a system which enables us to treat very small entities such as atoms in terms of probabilities but not as certainties."

Miss E. M. Fuller presented the first in a series of short book reviews. She dealt with the four volumes already published in the "Harvard Books on Astronomy" series which will run to nine volumes. "The series is well illustrated with attractive diagrams and photographs, and when completed will provide a survey of the most up-to-date work in astronomy," she said.

Dr. F. Shirley Jones then gave the introductory talk in a short course on "Spectroscopy" to be presented at the five autumn meetings. She followed her remarks with the showing of a motion picture film depicting the manufacture of optical glass, especially for defence purposes, at the government-owned plant of Research Enterprises Limited in Leaside.

FREDERIC L. TROYER, *Recorder.*

October 27, 1942.—The Society met at the usual place and hour, Dr. D. W. Best in the chair.

Two persons were duly elected to membership in the Society, viz:

Mr. Andrew Gage, 14 Henry Street, Toronto, and

Mr. Jack Neill, 47 Jameson Avenue, Toronto.

Mr. W. E. Knowles Middleton of the Meteorological Service of Canada then addressed the Society on "Meteorological Instruments of the Twentieth Century." He traced the development of the modern instruments from those of earlier centuries and referred particularly to some of the improvements and

modifications developed in Toronto by the Meteorological Service to meet peculiar Canadian needs. "Toronto's part in the history of meteorology and the development of meteorological instruments is by no means negligible," Mr. Middleton said.

Declaring that "Toricelli's barometer is, in my opinion, probably the most important single discovery in physics," the speaker said he hoped the Royal Astronomical Society of Canada might co-operate with the Canadian section of the Royal Meteorological Society in observing the 300th anniversary of the Toricelli barometer during the autumn of 1943. "This discovery revolutionized physics and caused many eminent gentlemen to run the risk of getting their heads cut off," Mr. Middleton said.

Probably the oldest barometer still in first-class working order is the one brought to Toronto from England in August 1839 and now located in the headquarters of the Meteorological Service, the speaker said. A Kew barograph, also at the Toronto observatory, had been in use from 1885 until a few months ago, and was still in excellent condition although now reserved for emergency use only, he added. The very accurate pressure readings measured on the barograph or recording barometer were of immense importance to geophysicists in determining the small tides produced in the earth's atmosphere by the moon, Mr. Middleton pointed out. He went on to describe the process by which mercury barometer tubes are filled at the Toronto observatory. Mercury, after being distilled several times, is run into glass tubes previously thoroughly dried out in an electric furnace, he said.

Besides the more commonly known weather instruments such as the barometer, barograph, thermometer, thermograph, anemometer, anemograph, rain guages, etc., the speaker described the development of hygrometers, psychrometers and hydrographs used to obtain humidity records which are especially important to the forest protection service. The earliest known design of such a device is found in the drawings of Leonardo da Vinci who suggested a wool ball and counterweight on opposite ends of a balance, the ball falling when it absorbed moisture from the air. About 1780 came a humidity recorder using a human hair, and the modern hydrograph is based on the same principle, Mr. Middleton said.

Recent developments in meteorology in which forecasting depends more and more on knowledge of conditions in the upper atmosphere, and the requirements of this knowledge for aviation, have brought into use new instruments such as the balloon meteorograph, recording devices carried aloft by plane, and the radiosonde which transmits reports on temperature, pressure and humidity back to a ground station by short-wave radio signals. The instrument, light in weight, is carried to high altitudes by balloon, and the revolving mechanism run by small flashlight batteries with "something less than one mouse-power" sends the radio signals to the ground receiving station.

Another fact of importance to aviators is the height of the "ceiling." This was previously determined by noting the height at which a coloured balloon dis-

appeared into the clouds. The more modern method is to study the reflection of a bright spotlight focussed on the clouds, but this is only feasible at night. A new method is now being perfected which utilizes a flashlight light which can be seen with suitable equipment even in bright daylight.

Looking to the future, Mr. Middleton said automatic weather stations located on mountain tops or in other inaccessible places were quite feasible except for one problem: that of making them sufficiently durable to withstand violent storms. When this drawback is solved such stations could be left unattended and could transmit radio signals to central stations giving complete information about the weather encountered hour by hour at the distant stations, Mr. Middleton concluded.

Miss E. M. Fuller presented a short review of *The New Handbook of the Heavens* by Bernard, Bennett and Rice. "This is neither a textbook nor a popular book, but is especially designed for the reader who has gone sufficiently far on his own to be interested in doing a little practical astronomical observing," she said.

Dr. F. Shirley Jones presented the second in the course of short lectures on "Spectroscopy." Detailing some of the fundamental principles of optics, Dr. Jones explained "what happens to the light that goes into the spectroscope." The index of refraction, she pointed out, depends on both the type of glass used in the lens or prism and the colour of the light. The deviation varies with the angle of the prism. The dispersion or spread of the rainbow of light is dependent on the type of glass and size of the prism. The speaker went on to describe compound prisms, single lens which may be considered as a series of little prisms, and compound lens. She detailed the errors which are found in the focussed image and their causes such as chromatic aberration, spherical aberration, coma, astigmatism and distortion.

FREDERIC L. TROYER, *Recorder.*

The Royal Astronomical Society of Canada

OFFICERS FOR 1942

Honorary President—THE HON. DUNCAN MCARTHUR, PH.D., Minister of Education for the Province of Ontario
President—FRANK S. HOGG, PH.D., Toronto
First Vice-President—MISS A. VIBERT DOUGLAS, PH.D., Kingston
Second Vice-President—A. E. JOHNS, PH.D., Hamilton
General Secretary—E. J. A. KENNEDY, 198 College St., Toronto
General Treasurer—J. H. HORNING, M.A., Toronto
Recorder—H. W. BARKER, Toronto
Librarian—P. M. MILLMAN, PH.D., Toronto
Curator—R. S. DUNCAN, Toronto
Council—D. S. AINSLIE, PH.D., Toronto; S. C. BROWN, Toronto; H. BOYD BRYDON, Victoria; J. W. CAMPBELL, PH.D., Edmonton; GEO. E. CAMPBELL, M.A., Hamilton; REV. W. G. COLGROVE, London; DEAN H. F. HALL, Montreal; E. A. HODGSON, PH.D., Ottawa; H. P. NEWTON, Vancouver; MISS F. S. PATTERSON, PH.D., Toronto; ANDREW THOMSON, PH.D., Toronto; L. A. H. WARREN, PH.D., Winnipeg; and Past Presidents—C. A. CHANT, LL.D.; A. T. DELURY, LL.D.; A. F. MILLER; J. R. COLLINS; W. E. W. JACKSON, M.A.; R. M. STEWART, M.A.; H. R. KINGSTON, PH.D.; R. K. YOUNG, PH.D.; L. GILCHRIST, PH.D.; R. E. DELURY, PH.D.; WM. FINDLAY, PH.D.; J. A. PEARCE, PH.D., and the presiding officer of each Centre.

TORONTO CENTRE

Honorary Chairman—C. A. CHANT, M.A., PH.D., LL.D.
Chairman—D. W. BEST, D.D. *Vice-Chairman*—MISS RUTH NORTHCOTT, M.A.
Secretary—TRACY D. WARING, 44 Rosepark Drive *Treasurer*—T. H. MASON
Recorder—F. L. TROYER *Curator*—R. S. DUNCAN
Council—D. S. AINSLIE, PH.D.; L. GILCHRIST, PH.D.; J. F. HEARD, PH.D.; F. S. HOGG, PH.D.; J. H. HORNING, M.A.; P. M. MILLMAN, PH.D.; REV. C. H. SHORTT, M.A.; R. K. YOUNG, PH.D.; W. T. PATTERSON, R.O.; MISS E. M. FULLER, B.L.S.; H. DUNCALFE; and Past Chairmen—J. R. COLLINS, E. J. A. KENNEDY, and S. C. BROWN

OTTAWA CENTRE

Honorary President—MISS MIRIAM S. BURLAND *President*—F. W. MATLEY
First Vice-President—T. L. TANTON, PH.D. *Second Vice-President*—HOYES LLOYD
Secretary—MALCOLM M. THOMSON, Dominion Observatory
Treasurer—ANDREW C. STEEDMAN
Council—MRS. A. A. LOWES; H. M. BRADLEY; C. B. REILLY, K.C.; W. W. NICHOL, B.A.; R. J. MCDIARMID, PH.D.; and Past Presidents—JOHN MCLEISH, B.A.; A. H. MILLER, M.A.; R. G. MADILL, B.A.

HAMILTON CENTRE

Honorary President—W. T. GODDARD *President*—H. B. FOX
Secretary-Treasurer—J. R. GRAHAM, 64 Blake St. *Curator*—T. H. WINGHAM, B.A.Sc.
Council—F. H. BUTCHER, B.A.; T. M. NORTON, WM. FINDLAY, PH.D.; A. E. JOHNS, PH.D.; G. E. CAMPBELL, M.A.; W. S. MALLORY, M.A.; REV. E. F. MAUNSELL; MISS N. CORKE; MISS G. MASON

WINNIPEG CENTRE

Honorary President—MONSIGNOR T. W. MORTON *President*—L. W. KOSER
First Vice-President—V. C. JONES *Second Vice-President*—MISS O. A. ARMSTRONG
Treasurer—R. S. EVANS
Secretary—MISS M. E. WATTERSON, 612 Toronto General Trusts Bldg.
Council—R. D. COLQUETTE; L. J. CROCKER; C. A. E. HENSLEY; W. P. JOHNSON; G. P. MORSE; H. E. RITER; A. W. SMITH; A. V. THOMAS; PROF. L. A. H. WARREN; P. C. WATT

MONTREAL CENTRE

Honorary President—MGR. C. P. CHOQUETTE
President—D. P. GILLMOR, K.C. *Vice-President*—G. H. HALL
Secretary—H. F. HALL, Sir George Williams College, 1441 Drummond St.
Treasurer—F. J. DEKINDER
Council—O. A. FERRIER; DELISLE GARNEAU; A. M. DONNELLY; G. R. LIGHTHALL; E. P. MORGAN; E. RUSSELL PATERSON; DR. W. B. ROSS; DR. A. M. SHAW

VICTORIA CENTRE

Honorary President—GORDON SHAW *President*—R. M. PETRIE, PH.D.
First Vice-President— *Second Vice-President*—O. M. PRENTICE
Secretary-Treasurer—MISS M. OLIPHANT, 986 Wilmer St.
Recorder—ROBERT PETERS *Librarian*—MISS C. HAILSTONE
Director of Telescope Making Section—W. HOBDAY
Council—MISS Y. LANGWORTHY; A. MCKELLAR, PH.D.; J. MOULSON; W. STILWELL, M.A.; MARK TRUEMAN; K. O. WRIGHT, PH.D.

LONDON CENTRE

Honorary President—DR. H. R. KINGSTON
Past President—REV. W. G. COLGROVE, M.A., B.D.
President—T. C. BENSON *Vice-President*—DR. G. R. MAGEE
Secretary-Treasurer—DR. RANDAL H. COLE, University of Western Ontario
Council—REV. M. E. CONRON; MRS. G. E. WOOD; J. W. BRYCE; E. H. MCKONE; D. M. HENNIGAR

VANCOUVER CENTRE

Honorary President—DR. J. A. PEARCE, Dominion Astrophysical Observatory
President—A. OUTRAM *Vice-President*—N. D. B. PHILLIPS
Recording Secretary—R. E. G. LANGTON, M.A.
Corresponding Secretary—H. D. SMITH, PH.D., Dept. of Physics, University of British Columbia
Treasurer—MRS. LAURA ANDERSON
Council—C. JORGENSON; MRS. C. A. ROGERS; F. R. STEWART; C. E. BASTIN; DR. RALPH HULL; F. G. BERTON; DR. VOLKOFF; M. A. MCGRATH

(Continued at bottom of next page)

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA
1890-1942

The Society was incorporated in 1890 under the name of The Astronomical and Physical Society of Toronto, and assumed its present name in 1903.

For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal and Quebec, P.Q.; Ottawa, Toronto, Hamilton and London, Ontario.; Winnipeg, Man.; Edmonton, Alta.; Vancouver and Victoria, B.C. As well as about 700 members of these Canadian Centres, there are over 200 members not attached to any Centre, mostly resident in other nations, while some 300 additional institutions or persons are on the regular mailing list for our publications.

The Society publishes a monthly JOURNAL containing about 500 pages and a yearly OBSERVER'S HANDBOOK of 80 pages. Single copies of the JOURNAL or HANDBOOK are 25 cents, postpaid. In quantities of 10 or more copies, the price is 20 cents a copy.

Membership is open to anyone interested in astronomy. Annual dues, $2.00; life membership, $25.00. Publications are sent free to all members or may be subscribed for separately. Applications for membership or publications may be made to the General Secretary, 198 College St., Toronto.

The Society has for Sale:

Reprinted from the JOURNAL of the Royal Astronomical Society, 1936-1942.

The Physical State of the Upper Atmosphere, (revised 1941) by B. Haurwitz, 96 pages; Price 75 cents postpaid.

General Instructions for Meteor Observing, (revised 1940) by Peter M. Millman, 24 pages; Price 15 cents postpaid.

A. H. Young's Simple Mounting for the 6-inch Reflector, by H. Boyd Brydon, 16 pages; Price 10 cents postpaid.

The Visual Photometry of Variable Stars, by H. Boyd Brydon, 64 pages; Price 50 cents postpaid.

A Yoke Mounting for the Six-inch Telescope, by H. Boyd Brydon, 8 pages; Price 10 cents postpaid.

In quantities of ten or more copies, a discount of 20 per cent will be allowed. Send Money Order to 198 College St., Toronto.

(Continued from previous page)

EDMONTON CENTRE

Honorary President—J. W. CAMPBELL, PH.D.
President—MRS. G. A. CLARKE *Vice-President*—J. A. MCLEAN
Secretary—E. H. GOWAN, PH.D., University of Alberta
Treasurer—E. N. HIGINBOTTHAM *Librarian*—E. S. KEEPING, PH.D.
Council—H. R. LEAVER; C. G. WATES; G. W. ROBERTSON; A. COTSMAN; J. J. TUCK

QUEBEC CENTRE

Honorary President—ARTHUR SMITH, formerly Director of the Quebec Observatory
President—HENRI PAUL KOENIG, M.Sc. *Vice-President*—ALBERIC BOIVIN
Treasurer—LUCIEN POULIOT, C.A. *Secretary*—PAUL H. NADEAU, 275 rue St-Cyrille, Quebec
Assistant-Secretary—LIONEL GALLICHAN
Council—A. AMOS, C.I.; ABBE R. BENOIT; R. F. JOACHIM, F.E.C.; J. C. MAGNAN; M. L. CARRIER, C.I.; L. MASSE, D.Sc.; J. A. DUMONT; V. CARON, President Junior Section; G. H. MONTREUIL, Organizer Junior Section.